M.O. 702

Price 2s. 6d. Net Monthly

THE METEOROLOGICAL MAGAZINE

May 1961

No. 1,066, Vol. 90

CONTENTS

MAY 1961

NOTICES

It is requested that all Books for Review and Communications for the Editor be addressed to the Director-General, Meteorological Office, London Road, Bracknell, Berkshire, and marked "for Meteorological Magazine".

The responsibility for facts and opinions expressed in the signed articles and letters published in this magazine rests with their respective authors.

All inquiries relating to the insertion of advertisements in the Meteorological Magazine should be addressed to the Director of Publications, H.M. Stationery Office, Atlantic House, Holborn Viaduct, London E.C.1. (Telephone: CITy 9876, extn. 147).

Printed in England by Geo. Gibbons Ltd., Leicester
and published by
HER MAJESTY'S STATIONERY OFFICE

Price 2s. 6d. **Annual subscription 32s. including postage**

(K15) S.O. Code No. 40-43-61-5

M.O. 702 AIR MINISTRY

METEOROLOGICAL OFFICE

THE METEOROLOGICAL MAGAZINE

VOL. 90, No. 1,066, MAY 1961

551.524.733: 551.557.33

FLUCTUATIONS IN TROPICAL STRATOSPHERIC WINDS

By R. G. VERYARD, B.Sc. and R. A. EBDON

Summary.—It has been found that there is a 23–29-month fluctuation in the zonal component of the stratospheric winds over the tropical regions from the equator to nearly 30°N. Insufficient observations are obtainable for upper air stations in southern tropical regions to indicate whether the fluctuation exists down to 30°S but such data as are available suggest that this may well be so. It appears that the fluctuation occurs almost simultaneously at the same level all round the tropics but there is a phase lag from higher to lower levels amounting to five to six months between the 25 mb and 60 mb levels. The range (twice amplitude) of the fluctuation increases with height but decreases polewards, for example, *as indicated by 12-monthly running means*, from approximately 30 knots at 60 mb and 70 knots at 30 mb at Christmas Island to approximately 10 knots at 60 mb and 15 knots at 30 mb at San Juan (Puerto Rico). Owing to the inadequacy and unreliability of the relevant temperature data it has not been possible to establish any link between the wind régime and the temperature pattern but the available observations for Canton Island suggest that a westerly régime is accompanied by warmer temperatures than an easterly régime. No firm evidence has been obtained that the fluctuation extends down into the troposphere.

Introduction.—In a recent letter to *Nature*[1] attention was drawn to a remarkable fluctuation with a period varying between 23 and 29 months in the zonal component of stratospheric winds recorded at equatorial upper air stations. It was mentioned that the fluctuation occurred almost simultaneously at the same level at each of the few stations for which adequate data were available but that there was a phase lag of several months between the occurrence of the fluctuation at lower levels compared with higher levels. It was also mentioned that results obtained up to that time indicated that the fluctuation also occurred at some distance, at least 10° of latitude, away from the equator. This paper gives a detailed account of the study and brings the findings up-to-date, findings which show that the fluctuation extends from the equator to nearly 30°N.

Equatorial stratospheric winds.—In an initial report[2] on the fluctuation of stratospheric winds at Christmas Island (02°00′N, 157°23′W) and Canton Island (02°46′S, 171°43′W), the impression was given that the fluctuation embraces a swing from a mainly westerly régime to a mainly easterly régime and also that the wind changes are apparent from daily observations and are not only revealed when long-period means are worked out. Subsequent work has shown that, whilst this is largely true for upper air stations close to the equator, the broad-scale fluctuation, that is over the tropical regions as a whole,

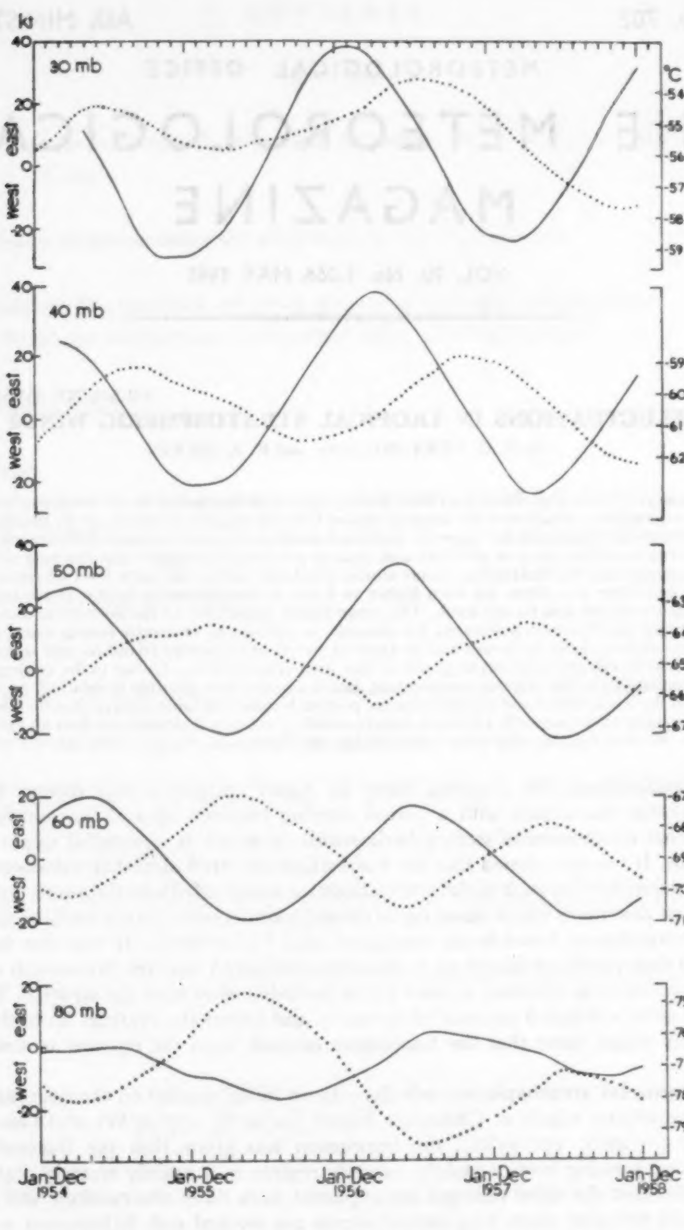


FIGURE 1—TWELVE-MONTHLY RUNNING MEANS OF ZONAL WIND COMPONENT (CONTINUOUS CURVES) AND TEMPERATURE (DOTTED CURVES) AT CANTON ISLAND

really consists of an oscillation of the *zonal component* of the stratospheric winds, for example, between strong and weak easterlies as well as between westerlies and easterlies, and it may not be detected unless the annual variation is removed (for example by using 12-monthly running means).

It is not proposed to reproduce in this paper the figures (Nos. 1 and 2) in the initial report in which are plotted actual values of the mean monthly zonal and meridional components of wind at stratospheric levels at Christmas Island and Canton Island. However, to supplement the picture so given, the values for the period 1954–58 for Canton Island are given in Table I and curves of 12-monthly running means of the zonal component at the 30, 40, 50, 60 and 80 mb levels are shown in Figure 1 for Canton Island and in Figure 2 for

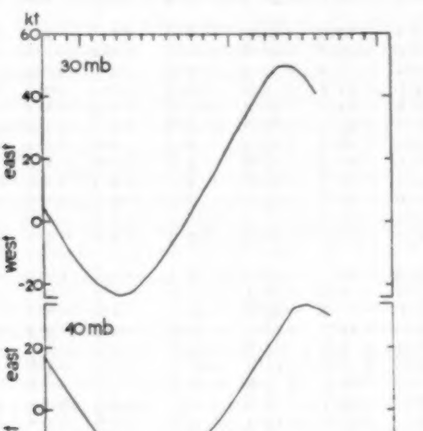


FIGURE 2—TWELVE-MONTHLY RUNNING MEANS OF ZONAL WIND COMPONENT AT CHRISTMAS ISLAND

TABLE I—MONTHLY MEANS (IN KNOTS) OF STRATOSPHERIC WIND COMPONENTS AT CANTON ISLAND, 1954–58

	Zonal components					Meridional components				
1954	30mb	40mb	50mb	60mb	80mb	30mb	40mb	50mb	60mb	80mb
Jan.			−16·3	−17·7	−16·7			−0·2	+1·8	+1·5
Feb.			− 4·7	− 2·0	− 0·2			−2·7	−0·8	+2·5
Mar.		+ 0·6	−12·8	−16·9	− 8·2		−3·1	−7·2	−1·5	−2·3
Apr.		+ 6·7	− 7·0	−14·2	−16·3		+3·1	+3·7	−0·8	−3·1
May	+46·3	+28·9	+24·8	− 5·6	−19·2	−3·1	+1·0	−0·4	−2·1	0·0
June	+41·4	+37·3	+28·7	+ 9·7	− 7·4	+4·3	+7·4	+1·4	−0·2	+1·4
July	+59·9	+47·6	+40·6	+20·9	+ 2·5	−1·5	−2·0	+1·5	+0·8	+1·2
Aug.	+50·9	+49·4	+44·1	+24·3	+14·2	+2·9	0·0	−0·8	+1·2	+0·8
Sept.	+36·8	+53·8	+44·4	+25·9	+17·9	−1·7	−0·8	+0·6	+2·2	−0·6
Oct.	+14·2	+55·8	+48·0	+29·1	+10·5	−1·2	−2·9	0·0	+4·1	−0·2
Nov.	−12·8	+27·0	+41·4	+34·2	+ 4·9	−3·3	−1·5	+1·7	+1·8	0·0
Dec.	−14·0	+10·7	+38·6	+31·5	− 3·9	−1·5	0·0	+0·4	+2·9	−1·7
1955										
Jan.	−17·1	−14·2	+14·0	+24·3	− 0·8	+1·5	−2·2	+1·4	−2·7	−0·6
Feb.	−22·4	− 8·0	+ 5·1	+21·8	−10·1	+0·2	−1·0	+1·0	+0·4	−6·8
Mar.	−20·0	−10·1	− 4·2	+14·4	+ 0·8	+2·5	+0·4	−1·2	−3·0	−2·9
Apr.	−26·3	−24·9	−21·1	− 8·6	−13·4	−0·4	−0·2	−1·0	−0·7	−0·2
May	−37·3	−28·6	−23·1	−12·2	−11·1	+1·5	−1·2	−0·6	+0·4	−2·7
June	−36·4	−32·8	−29·9	−24·8	− 6·6	+3·3	+1·0	+2·7	+0·9	−0·6
July	−36·0	−27·0	−18·3	−13·5	+ 0·4	0·0	+1·4	+0·2	+0·7	−1·2
Aug.	−62·6	−30·3	−22·2	−15·6	− 4·3	+0·6	−1·0	+2·3	+0·7	−1·5
Sept.	−32·8	−24·5	−20·6	−19·6	− 9·1	+2·7	+2·7	+2·5	+1·8	+0·2
Oct.	−30·5	−22·8	−19·6	−14·9	− 7·2	−0·3	+2·0	+0·8	−1·3	−0·2
Nov.	− 7·6	−13·0	−22·6	−31·1	−25·3	+3·3	−1·0	+1·0	0·0	−3·7
Dec.	−12·6	−11·7	−17·9	−18·5	−17·3	+2·0	+3·1	−1·8	−1·8	−2·3
1956										
Jan.	− 2·2	−10·9	−13·7	−17·3	− 8·1	−1·8	+0·9	−0·3	−2·1	−2·3
Feb.	+10·5	− 6·6	−12·8	−16·4	−13·6	−1·5	−0·1	−1·0	−2·5	−3·6
Mar.	+19·3	− 6·1	−18·2	−19·2	−20·7	−2·0	−3·7	−0·7	+0·1	−3·9
Apr.	+35·3	+ 8·2	−15·7	−22·1	−31·4	−2·3	−3·4	+1·1	+2·1	+0·4
May	+42·7	+27·9	+ 2·7	−21·6	−29·7	−1·4	−0·2	−1·3	+0·3	−0·6
June	+50·5	+36·2	+17·8	−13·8	−20·1	−0·3	+4·6	+1·4	−1·7	+0·1
July	+48·2	+41·9	+29·5	+ 4·6	− 8·7	−0·6	−0·6	+0·6	+2·5	+1·0
Aug.	+51·7	+47·2	+33·7	+ 7·8	− 0·4	+1·3	+0·9	+1·9	+0·9	+1·9
Sept.	+55·6	+48·0	+32·6	+13·4	+ 7·2	+0·6	+1·1	+1·6	+2·3	−1·0
Oct.	+65·5	+48·8	+39·1	+18·3	+ 0·2	0·0	0·0	+1·2	+1·7	−0·2
Nov.	+51·1	+53·5	+42·1	+20·1	− 2·7	−0·8	−1·1	−0·3	−1·8	−3·3
Dec.	+24·2	+58·2	+42·8	+25·6	+ 5·0	−1·4	+0·5	0·0	−1·5	+2·5
1957										
Jan.	+ 1·1	+50·0	+44·7	+24·1	+ 8·0	−2·3	−1·2	−0·2	−1·7	−3·4
Feb.	+ 4·5	+44·5	+42·7	+30·6	+ 6·8	−5·4	0·0	+0·6	−0·9	+1·3
Mar.	−18·8	+24·4	+43·2	+26·9	+ 7·4	−1·6	−0·9	−1·0	0·0	+2·8
Apr.	−22·6	− 5·4	+34·8	+23·4	+ 2·5	+0·1	−1·6	−0·8	−0·8	−2·1
May	−28·2	−22·9	+ 7·9	+19·9	+ 8·3	+0·1	+0·2	−2·6	−0·6	0·0
June	−26·4	−25·3	−18·2	− 2·9	+10·5	0·0	+1·8	+1·2	+1·5	+0·9
July	−26·8	−27·7	−21·9	− 9·5	+ 6·0	+2·2	+0·5	+0·1	−3·2	+0·4
Aug.	−30·5	−27·8	−25·2	−15·3	− 2·2	+3·6	+0·1	+0·4	+0·2	−0·9
Sept.	−46·1	−27·5	−23·2	−12·7	− 0·2	−1·3	−0·4	+2·0	+0·9	+2·9
Oct.	−30·3	−27·1	−23·1	−17·1	− 6·3	+0·2	+1·7	−1·4	+0·2	+1·3
Nov.	−15·6	−25·6	−24·2	−23·1	− 7·0	−0·9	−2·3	−1·5	−2·9	−1·3
Dec.	−10·7	−22·2	−23·1	−21·1	− 9·1	−0·5	−0·5	+0·4	−0·5	−1·1
1958										
Jan.	−12·9	−22·1	−18·8	−13·9	− 5·5	−0·4	+0·4	−0·2	+2·7	−1·2
Feb.	−12·3	−18·9	−15·7	−16·2	− 4·9	−0·4	−2·0	−0·1	+1·8	−0·2
Mar.	− 8·1	−18·7	−17·7	−10·4	− 6·2	−1·2	−0·2	−0·6	−0·5	−1·1
Apr.	+ 9·1	−19·5	−21·3	−18·6	− 7·4	+1·2	+1·9	+1·7	+1·1	+0·6
May	+38·0	+ 3·4	−24·6	−31·3	−24·4	−1·4	−0·5	−0·9	+0·3	+0·9
June	+43·0	+18·1	−19·0	−28·6	−17·0	+0·8	+1·9	+1·1	+0·1	−1·1
July	+43·6	+25·2	− 7·2	−20·1	− 7·3	−0·3	+0·3	−0·5	−0·5	+0·6
Aug.	+48·6	+30·0	− 0·5	−14·6	− 3·5	−1·3	−0·8	−2·6	+1·1	−1·5
Sept.	+51·5	+36·9	+ 4·7	− 9·5	− 5·4	0·0	+0·3	+0·3	+0·4	+1·0
Oct.	+59·5	+41·6	+13·9	− 4·2	− 8·1	+2·0	0·0	−1·5	+1·5	−1·1
Nov.	+61·8	+46·2	+23·1	+ 6·0	+ 4·4	0·0	+2·3	−1·8	−0·4	−0·4
Dec.	+61·5	+45·8	+26·9	+ 9·0	+ 3·8	−2·8	−2·3	+0·2	−0·9	+1·3

Note: Positive from north and east, negative from south and west.

Christmas Island. An extended curve for the 50 mb level at Canton Island, based on one hour of observation only, is given in Figure 15 which will be referred to later. Figures 3 and 4 respectively give similar curves for Nairobi (01°18'S, 36°45'E) at the 60 and 80 mb levels and for Singapore (01°20'N, 103°53'E) at 60,000 feet (about 65 mb). The data available for higher levels at Nairobi and Singapore were insufficient to enable reliable curves to be plotted; but for all the curves shown in Figures 1 to 4 at least 10 observations (and generally many more) were available for each month except for a few months in respect of the higher levels at Christmas Island. The general agreement between these curves will be seen at a glance but to illustrate the near simultaneity of the occurrence of the fluctuations at each of these stations, all of which are situated close to the equator, the curves for the 50 mb level at Christmas Island and Canton Island are superimposed in Figure 5 and the curves for the 60 mb level at Christmas Island, Canton Island and Nairobi plus the 60,000-foot (about 65 mb) level at Singapore are superimposed in Figure 6. In Figure 7 the curves for 80 mb at Christmas Island, Canton Island and Nairobi are also given together. It is unfortunate that the useful length of record and the number of observations available vary from station to station but the agreement of the curves in Figures 5–7 is most remarkable and significance tests are hardly necessary to support what seems to be a reasonable conclusion, namely, that a fluctuation varying between 23 months and 29 months in the zonal component of the stratospheric winds occurs almost concurrently at the same level all round the equator. Even short-period records, for example from the comparatively new upper air station at Gan (00°41'S, 73°10'E) and from Guaquil (02°11'S, 79°52'W) for which only some IGY data were available, confirmed the finding, as will be seen from Figure 8. This gives curves, for the 60 mb level, of the *actual* values of the monthly mean zonal wind components for these two stations and also for Canton Island, Nairobi and Christmas Island plus the 60,000-foot level at Singapore. The agreement of the curves for the last three stations during the peak in the easterlies in June 1959 is particularly noteworthy. Discontinuous or short-period data available for other stations near the equator, that is Entebbe (00°03'S, 32°27'E), Ikeja (06°35'N, 03°20'E), Recife (08°S, 53'W) and Truk Island (07°27'N, 151°50'E) also support the finding. A curve for the 50 mb level at Truk Island is superimposed in Figure 5 on the corresponding curves for Christmas Island and Canton Island. It will be noted that the range of the fluctuation (*as indicated by 12-monthly running means*) is 20–25 knots less at Truk Island, the station most distant from the equator, than at the other two stations, that is, there is a decrease at the 50 mb level of about three knots per degree of latitude. This feature of the fluctuation will be referred to again in the next section. To test the correspondence between the mean monthly zonal components at one station and another, correlation coefficients were determined. The results were as follows:

0·97 between 50 mb data for Christmas Island and Canton Island
0·94 between 60 mb data for Christmas Island and Nairobi
0·76 between 60 mb data for Christmas Island
0·80 between 60 mb data for Nairobi
and 60,000 ft (65 mb) data for Singapore with one-month lag (see below)

In the initial report already referred to, it was pointed out that the data for Christmas Island indicated a phase lag between the occurrence of the fluctuation at a higher level and a lower level, and also a decrease in the amplitude of

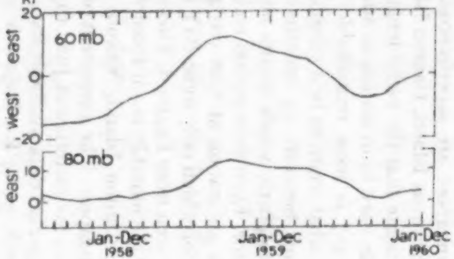


FIGURE 3—TWELVE-MONTHLY RUNNING MEANS OF ZONAL WIND COMPONENT AT NAIROBI

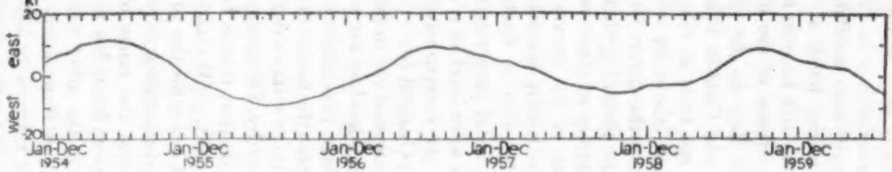


FIGURE 4—TWELVE-MONTHLY RUNNING MEANS OF ZONAL WIND COMPONENT AT 60,000 FT (ABOUT 65 MB) AT SINGAPORE

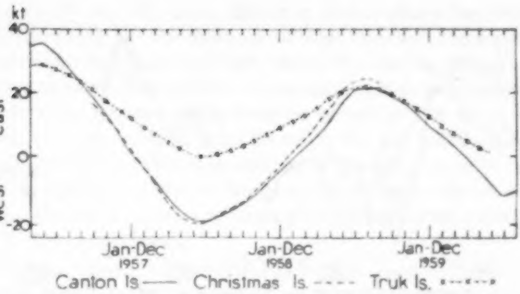


FIGURE 5—TWELVE-MONTHLY RUNNING MEANS OF ZONAL WIND COMPONENT AT 50 MB

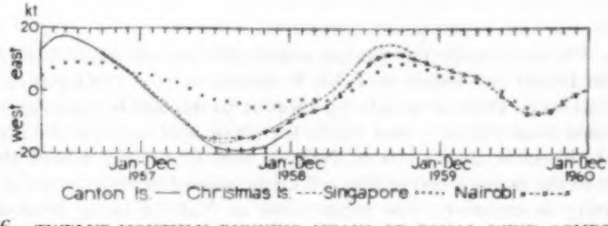


FIGURE 6—TWELVE-MONTHLY RUNNING MEANS OF ZONAL WIND COMPONENT AT 60 MB

For Singapore 60,000 ft was used.

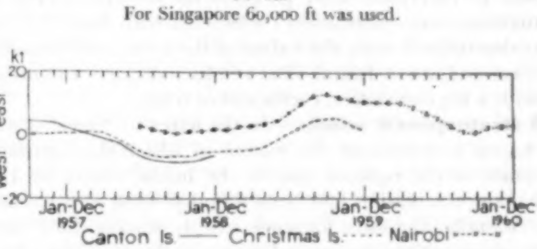


FIGURE 7—TWELVE-MONTHLY RUNNING MEANS OF ZONAL WIND COMPONENT AT 80 MB

the fluctuation from higher to lower levels. Both these features are revealed in Figures 1, 2 and 3 but it should be noted that the effect of using 12-monthly running means has been to reduce the amplitude in each case. In summary, the data for Canton Island and Christmas Island indicate that the average time-lag between peaks/troughs in the fluctuation at a higher level and at a lower level is about two months between 20 and 30 mb, one and a half months between 40 and 50 mb, and about one month between 50 and 60 mb, 60 and 70 mb, and 70 and 80 mb, which works out at about one month per kilometre change of height. The data for the 60 mb and 80 mb levels at Nairobi confirm this. Similarly, the range of the fluctuation (based on 12-monthly running means) decreases from about 70 knots at 30 mb to 60 knots at 40 mb, 45 knots at 50 mb, and 35 knots at 60 mb, which works out at a little less than 10 knots per

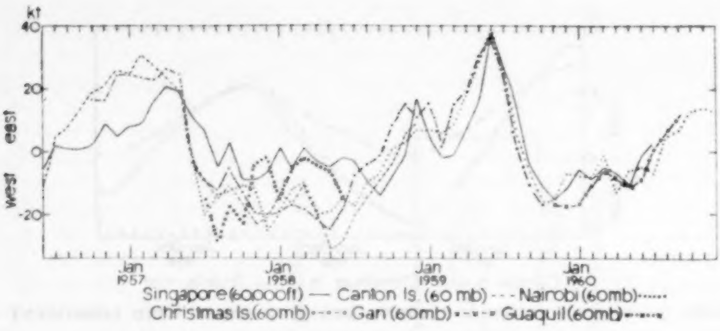


FIGURE 8—MONTHLY MEAN ZONAL WIND COMPONENTS

kilometre. The *actual* range, for example as indicated by individual monthly means for Canton Island (see values in Table I) decreases from 100 knots or more at 30 mb to about 90 knots at 40 mb, 75 knots at 50 mb and 65 knots at 60 mb. It will be noted from Figure 7 that whilst the phase and range of the fluctuation are about the same at 80 mb at Nairobi and Christmas Island there is a difference in the mean speed of about 8 knots (taking easterly winds as positive and westerly as negative), the mean wind at Nairobi being predominantly easterly whilst at Christmas Island there is an oscillation between westerly and easterly winds. To determine more precisely the dominant value of the period of the fluctuations, auto-correlation coefficients with lags of 1, 2, 3, 4 . . . *n* months were determined using the values of the 12-monthly running means for the 50 mb level at Canton Island. The results indicated a dominant period of 26 months with a lag correlation coefficient of 0·93.

Tropical stratospheric winds.—In the letter to *Nature*[1] it was mentioned that it was hoped to determine the extent to which the fluctuation extended north and south of the equator and in the initial report by Ebdon[2] it was indicated that the fluctuation had been found to exist at a few stations within the tropics. Actually, the data for some twenty stations have been examined but, in most cases, either the record was too short or the observations too few, especially for stations south of the equator, for it to be possible to make any reliable deductions. However, the data for a few stations were quite fruitful. Except for levels above 40 mb where the record was short, the observations available for San Juan, Puerto Rico (18°28′N, 66°07′W), were particularly good and it was possible to "marry" data for height levels as used before 1956 with data for pressure levels used from 1956 onwards. Because of a marked annual variation in the upper winds at this station, it was essential to use 12-monthly running means and such values of the zonal component for the 20, 25, 30 and 40 mb/22 km, 50 mb/20 km,* 60 mb/20 km,* and 80 mb/18 km levels are given in Figure 9†. That a fluctuation similar to that found for equatorial stations occurred at Suan Juan, but with a smaller amplitude, is quite obvious. It will be noted that the range of the fluctuation, *as indicated by 12-monthly running means*, decreases from about 15 knots at the 30 mb level to

* 20 km is about half-way between the 50 and 60 mb levels.

† It should be noted that in Figures 9–14 the scale for windspeed is twice that used in other figures.

about 10 knots at the 60 mb level. There is also a phase lag from higher to lower levels but, owing to the flatness of the "peaks"/"troughs", it is not possible to determine this very precisely from the curves. However, from the individual values of the 12-monthly running means it is estimated that, on the average, there is a lag of two months from 30 mb to 40 mb, three months from 40 mb to 60 mb, and two months from 60 mb to 80 mb, which again works out at about one month per kilometre change of height. It will be seen from Figure 9 that the period of the fluctuation varies from about 22 months to 29 months; lag correlation (with a coefficient 0·93) indicated a dominant period of 23 months at the 50 mb level.

Although the data were not so plentiful as for San Juan sufficient observations were available in most months for curves of the 12-monthly running means of the zonal component to be drawn for the 60 mb level at Aden (12°49'N, 45°02'E), Khartoum (15°36'N, 32°33'E), Bahrain (26°16'N, 50°37'E) and Malta (35°50'N, 14°27'E). The curves for Aden, Khartoum and Bahrain are given in Figure 10 together with the corresponding curve for Nairobi so as to provide, approximately, a north–south picture. It will be seen that although the fluctuation appears to be present at Bahrain in 1954–57 it is not detectable in later years—but the data were rather inadequate, especially for the winter months. It will also be noted that at the other stations, although the fluctuation remains approximately in phase at the same level (60 mb), the farther away the station is from the equator the smaller the range of the fluctuation, that is about 28 knots at Nairobi, 20 knots at Aden and 11 knots at Khartoum. In fact, the greater is the distance from the equator the greater the decrease per degree of latitude—the average decrease being about one knot per one degree of latitude (see also the remarks on observations at Truk Island in the previous section). At Malta there was no sign of the fluctuation and this was also the case at Crawley (51°05'N, 00°13'W) for both of which stations adequate data at 60 mb were available. As has already been noted, the range or amplitude of the fluctuation increases with height, and it might therefore have been possible to detect the fluctuation at higher levels at these more northern stations but, unfortunately, sufficient data were not available. Other stations for which curves of 12-monthly running means were drawn were Hilo (19°44'N, 155°04'W), Jacksonville (30°20'N, 81°40'W) and Washington (38°51'N, 77°02'W). The curves for the 40, 50, 60 and 80 mb levels at Hilo are given in Figure 11, for the 30, 40 and 50 mb levels at Jacksonville in Figure 12 and for the 20, 25, 30, 40, 50, 60 and 80 mb levels at Washington in Figure 13. In both Figures 11 and 12 the curves for corresponding levels at San Juan are superimposed. It will be noted that the curves for Hilo agree fairly well with the corresponding curves for San Juan, both stations being in approximately the same latitude, but that there is no corresponding fluctuation in the case of Jacksonville (or in the case of Washington). In fact, all these curves reveal the same north–south relationship as is shown by Figure 10, that is a decrease in amplitude with distance from the equator and its disappearance north of about 30°N. It is interesting to note that the curves for the 20, 25 and 30 mb levels at Washington and for the 30, 40 and 50 mb levels at Jacksonville suggest a fluctuation with an anti-phase relationship to that of the fluctuation in the tropics but the records are much too short for this to be certain; neither were data from other middle- or high-latitude stations adequate to provide any check.

In Figure 14 the 60 mb curves for San Juan and Khartoum, within 5° latitude of each other, are superimposed. This appears to confirm the suggestion that the fluctuation may occur almost simultaneously around a latitude circle as has already been indicated by the curves for stations near the equator. Correlation of the data (12-monthly running means) for San Juan and Khartoum gives a coefficient of 0·69.

Before concluding this section, it should be mentioned that the findings described above were supported by short-period data available from Charleston (32°54'N, 80°02'W) and Johnston Island (16°45'N, 169°32'W). High-altitude observations made at tropical stations over Australia (Hopper, V. D.)[3] suggest that the fluctuation may occur as far south as 20°S.

It will be noted with interest from Figures 1, 15, 4 and 9 that the three long-period records, that is for 50 mb at Canton Island, 60,000 feet for Singapore and 40, 50, 60 and 80 mb for San Juan (which demonstrate the existence of the fluctuation during the last nine to ten years) all show that in recent years the amplitude of the fluctuation has decreased. Maybe, like other alleged "periodicities" which have been discovered before, the fluctuation under discussion is only ephemeral and it will be interesting to see whether the fluctuation is maintained.

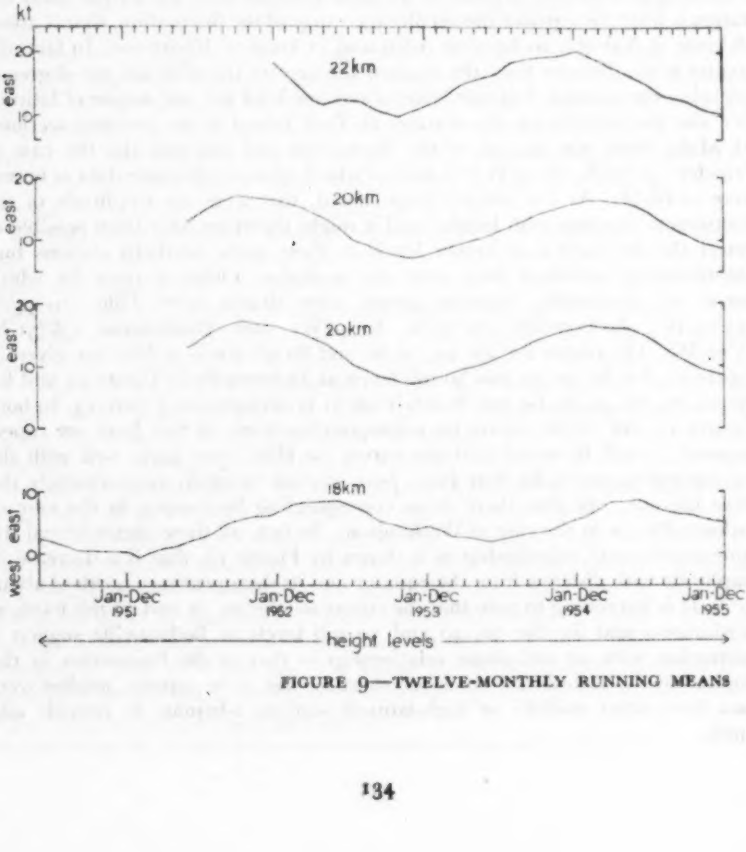
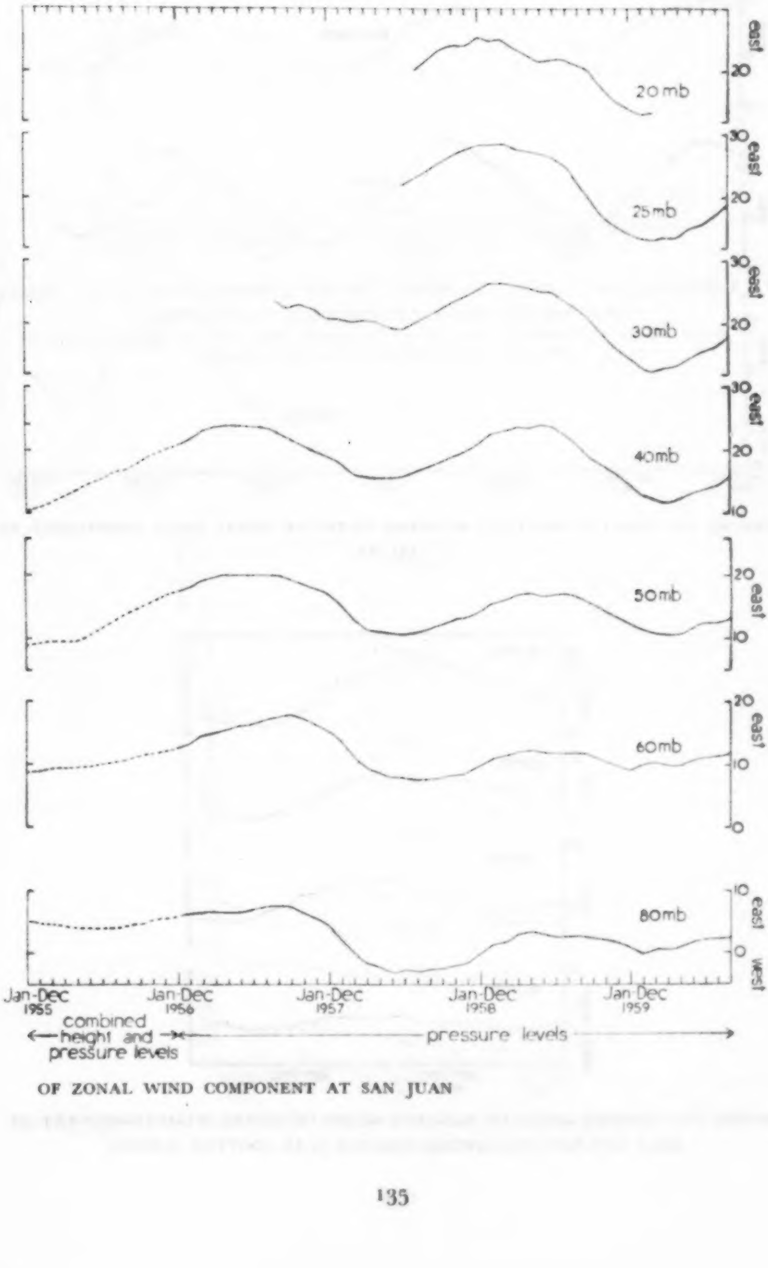


FIGURE 9—TWELVE-MONTHLY RUNNING MEANS



OF ZONAL WIND COMPONENT AT SAN JUAN

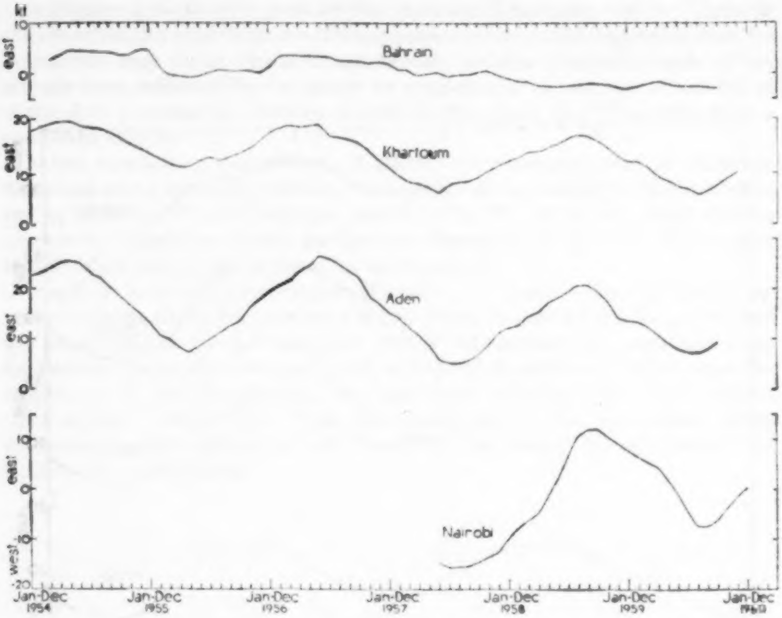


FIGURE 10—TWELVE-MONTHLY RUNNING MEANS OF ZONAL WIND COMPONENT AT 60 MB

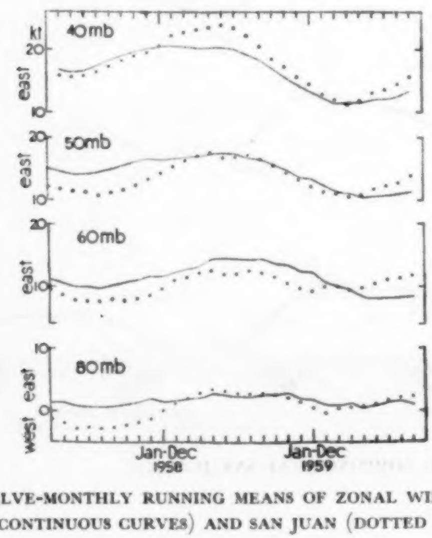


FIGURE 11—TWELVE-MONTHLY RUNNING MEANS OF ZONAL WIND COMPONENT AT HILO (CONTINUOUS CURVES) AND SAN JUAN (DOTTED CURVES)

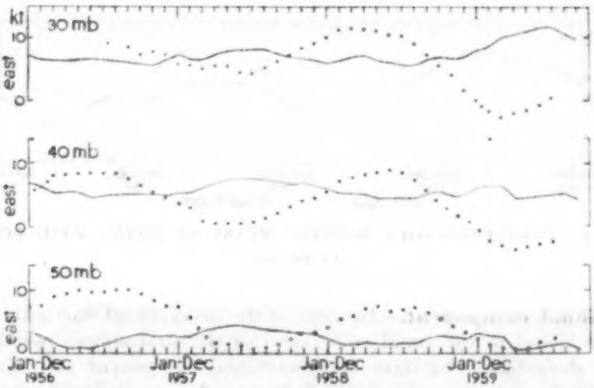


FIGURE 12—TWELVE-MONTHLY RUNNING MEANS OF ZONAL WIND COMPONENT AT JACKSONVILLE (CONTINUOUS CURVES) AND SAN JUAN

In superimposing the San Juan curves, 15 kt has been subtracted from the values at 30 and 40 mb and 10 kt from those at 50 mb.

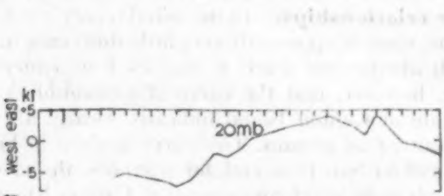


FIGURE 13—TWELVE-MONTHLY RUNNING MEANS OF ZONAL WIND COMPONENT AT WASHINGTON

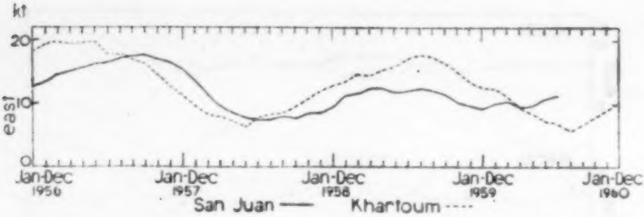


FIGURE 14—TWELVE-MONTHLY RUNNING MEANS OF ZONAL WIND COMPONENT AT 60 MB

Meridional component.—In view of the pronounced fluctuations which have been found in the zonal component of the stratospheric winds, it was obviously desirable to examine the meridional component also. But for no station did the relevant curves definitely reveal any similar fluctuation, although it should be mentioned that the meridional components were generally too small (especially at stations near the equator) to yield conclusive results. Auto-correlation of the values of the monthly mean meridional components for the various pressure levels at Canton Island and San Juan (both stations with good and fairly long records) did not reveal any marked fluctuation in the meridional component corresponding with that in the zonal component.

Temperature relationships.—In the initial report it was shown that, over the central Pacific, there is apparently very little difference in the temperature pattern at 50 mb whether the winds at that level are easterly or westerly. It was pointed out, however, that the curve of 12-monthly running means of 50 mb temperature at Canton Island indicated clearly a fluctuation with a periodicity of about 24–28 months. This curve is given in Figure 15 together with a similar curve for San Juan and, for reference, the 12-monthly running means of the 50 mb zonal wind components at Canton Island. It will be seen that there is a phase lag of one to two months between the Canton Island curves and that the San Juan curve shows no clear fluctuation (although there is, perhaps, a suggestion of a weak fluctuation in anti-phase with that at Canton Island). Examination of the temperature data available for Canton Island at other stratospheric levels, that is 80, 60, 40 and 30 mb, also revealed the existence of an approximately 26-month fluctuation at these levels—the range of the fluctuation, as indicated by 12-monthly running means, decreasing

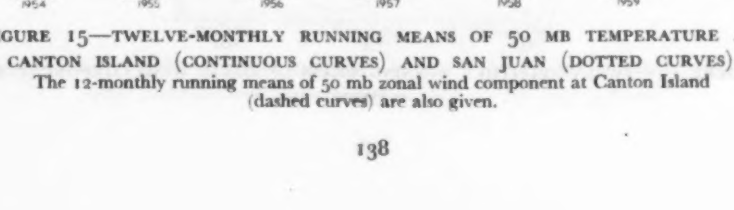


FIGURE 15—TWELVE-MONTHLY RUNNING MEANS OF 50 MB TEMPERATURE AT CANTON ISLAND (CONTINUOUS CURVES) AND SAN JUAN (DOTTED CURVES)
The 12-monthly running means of 50 mb zonal wind component at Canton Island (dashed curves) are also given.

[To face p.138

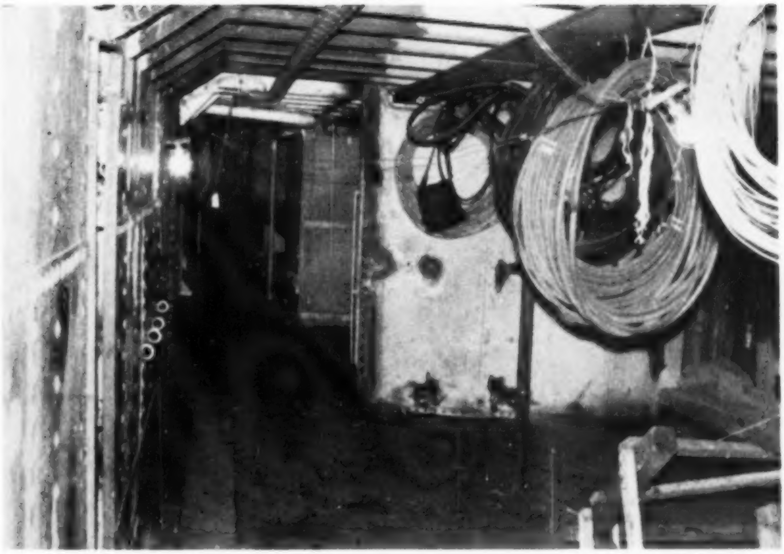
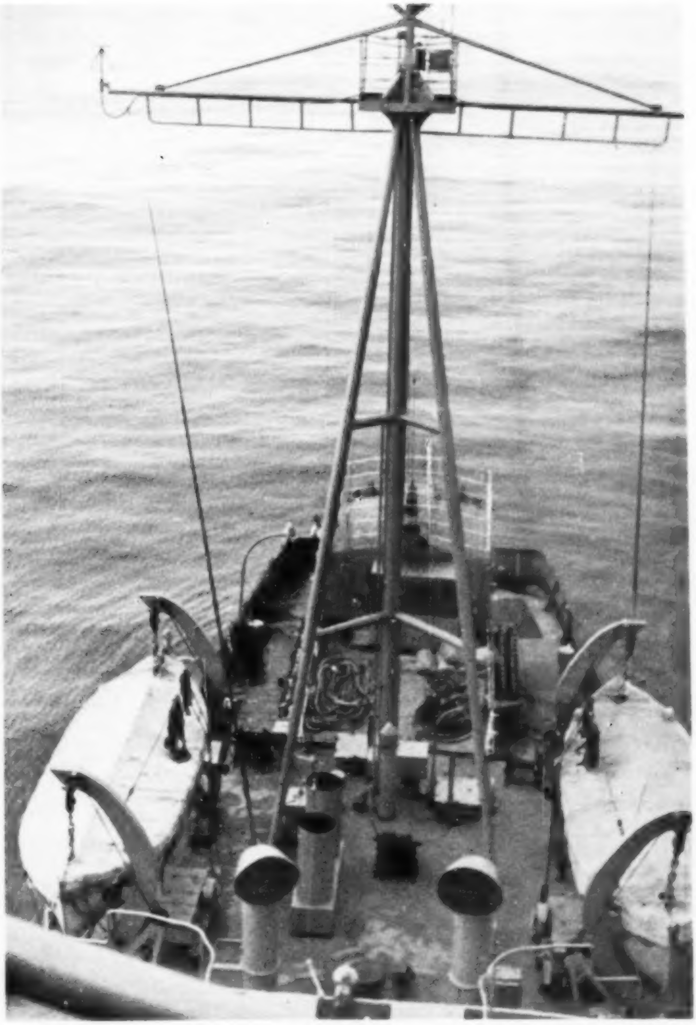


PLATE I—DURING THE CONVERSION STAGES IN FITTING OUT A WEATHER SHIP

Crown Copyright

PLATE II—A CABIN IN A NEWLY FITTED-OUT WEATHER SHIP



Crown Copyright

PLATE III—A FINE DAY AT SEA

[*To face p.139*

Crown Copyright

PLATE IV—"WEATHER WATCHER" AT SEA

upwards from 3°–4°C at 80 mb to 1·5°–2·5°C at 30 mb and the lag between the temperature change and the wind change increasing upwards from one to two months at 80 mb to about seven months at 30 mb (see Figure 1).

As might be expected from this increasing lag with height between the temperature change and the wind change, the differences between the 12-monthly running means of the temperatures at the various levels, for example, between 30 and 80 mb as shown by the curve in Figure 16 reveal that the fluctuation is also to be found in the mean vertical temperature gradient.

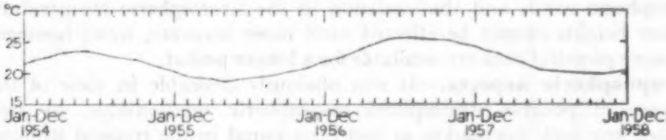


FIGURE 16—DIFFERENCES BETWEEN TWELVE-MONTHLY RUNNING MEANS OF TEMPERATURE AT 30 AND 80 MB AT CANTON ISLAND

In an attempt to amplify these results, 60 mb temperature data for Nairobi, Aden, Khartoum and Bahrain were examined and curves of 12-monthly running means covering the period July 1957 to December 1960 are given in Figure 17. It will be noted that for much of the relatively short period concerned there is a close agreement between the curves for Nairobi, Aden and Khartoum, but that there is little evidence for suggesting any fluctuation similar to that found in the 60 mb zonal wind component at these four stations. The number of 60 mb temperature observations at these stations was generally adequate except at Nairobi where ten of the monthly means had to be computed from less than ten observations.

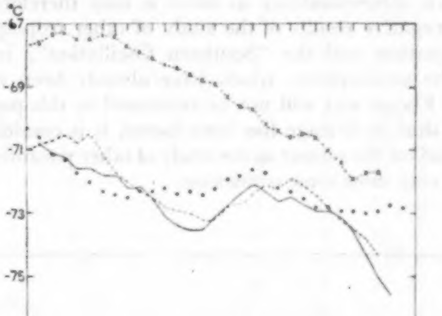


FIGURE 17—TWELVE-MONTHLY RUNNING MEANS OF 50 MB TEMPERATURE

It should be mentioned that there do not seem to be any other upper air stations near the equator with a stratospheric wind and temperature record comparable with that for Canton Island. Some rather doubtful temperature

data for Christmas Island did seem to support the finding for Canton Island but as the Nairobi data (which were scanty) did not, the question whether there is any general fluctuation of stratospheric temperature in equatorial regions linked with the fluctuation of the zonal winds cannot be answered at present.

Twelve-monthly running means of contour height at 50 mb and 60 mb were also examined for both equatorial and tropical stations but the results revealed no fluctuation with a periodicity of 23–29 months. Indeed, it seems that any attempt to find a relationship between the pronounced variations in the tropical stratospheric winds and the variation in the stratospheric temperature and contour heights cannot be effected until more accurate, more homogeneous and more plentiful data are available for a longer period.

Tropospheric aspects.—It was obviously desirable in view of the importance of possible stratospheric–tropospheric relationships, to ascertain whether any such fluctuation as had been found in the tropical stratospheric winds existed in the tropospheric winds; but, in confirmation of the earlier findings mentioned in the initial report by Ebdon,[2] no well defined parallelism was found. As an example, the curves for the 12-monthly running means of the zonal wind components at Canton Island for the 500 mb, 200 mb and 50 mb levels (mean tropopause about 90 mb) are given in Figure 18, and the 12-monthly running means of the zonal wind components at San Juan for the 500 mb/6 km, 300 mb/10 km, 200 mb/12 km and 100 mb/16 km levels (mean tropopause about 95 mb) are given in Figure 19. It will be noted that there is some correspondence between the tropospheric and stratospheric winds towards the end of the period (1957–59) at San Juan but this is not the case for the earlier parts of the curves. Moreover, in 1957–58 there appears to be a phase lag from lower to higher levels rather than from higher to lower levels as was found in the stratosphere. Actually the tropospheric curves which were drawn for Singapore and Christmas Island even suggested an anti-phase relationship. Such correspondence as there is may therefore be regarded as fortuitous. The negative results of the study of other tropospheric events (for example, precipitation and the "Southern Oscillation") in relation to the fluctuation in the stratospheric winds have already been mentioned in the initial report by Ebdon and will not be reiterated in this paper. However, in spite of the fact that no linkage has been found, it is considered advisable to keep an open mind on the subject as the study of other parameters (for example, vertical motion) may show some connexion.

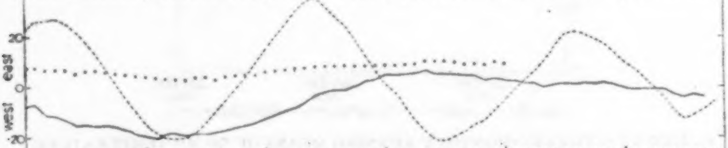


FIGURE 18—TWELVE-MONTHLY RUNNING MEANS OF ZONAL WIND COMPONENT AT CANTON ISLAND

50 mb: dashed curve; 200 mb: continuous curve; 500 mb: dotted curve

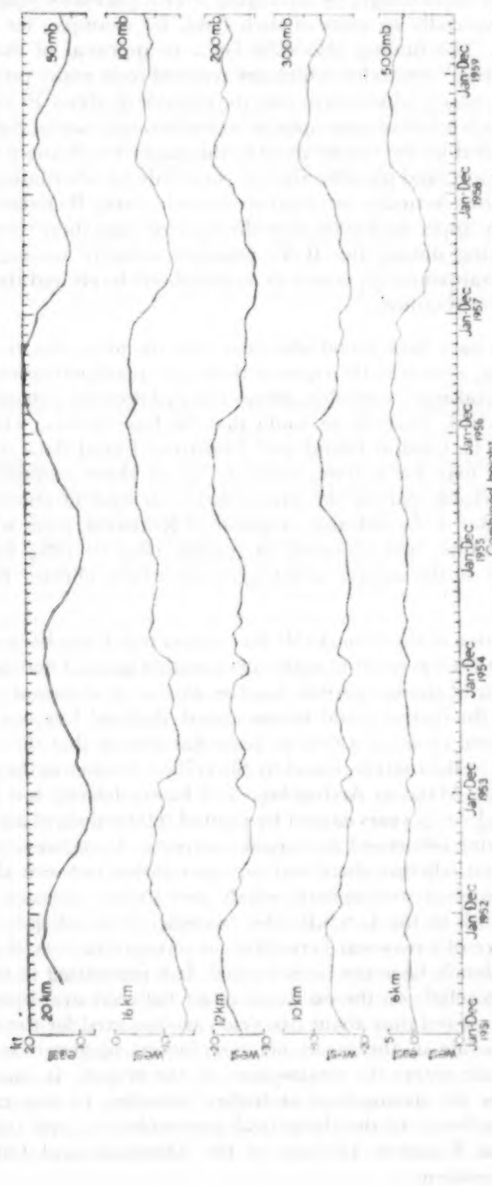


FIGURE 19—TWELVE-MONTHLY RUNNING MEANS OF ZONAL WIND COMPONENT AT SAN JUAN

Discussion.—The existence of the fluctuation in the stratospheric winds over tropical regions with a period which varies from about 23 months to 29 months indicates that a mean monthly, seasonal or yearly wind obtained, as is usually done in climatology, by averaging over a period of years will be very misleading—especially to users of such data, for example, for studying radioactive fall-out. The finding also calls for a re-appraisal of the alleged existence of the "Berson" westerlies which are referred to in many publications as a narrow belt of westerly winds encircling the equator at about 20 kilometres (50–60 mb). That such a belt of stratospheric westerlies *could* extend right round the equator is suggested by the results given in this paper but it might be found at *any* level up to 10 mb (and possibly above)—and only for alternating periods of about 12–15 months. Actually, attempts were made, using IGY data, to find occasions when every upper air station near the equator (and there were several new stations operating during the IGY) reported westerly winds; but the observations were disappointingly scarce at stratospheric levels and the desired evidence could not be obtained.

The results which have been found also show that the idea, also to be found in many publications, that over the equator there are quasi-permanent easterlies, the so-called "Krakatoa" easterlies, above the 25-kilometre (about 25 mb) level needs to be revised. There is no doubt that the base of these winds must vary considerably. The Canton Island and Christmas Island data show that the westerly régime may for a time, certainly up to three months, prevail throughout a considerable part of the stratosphere—at least to above 25 mb. Thus it is possible that if the volcanic eruption of Krakatoa, from which the easterlies get their name, had occurred in August 1882 or 1884 instead of August 1883, writers on the subject might have coined the phrase "Krakatoa westerlies"!

As for the explanation of the remarkable fluctuation which has been reported in this paper, it is not even possible to make a reasonable guess. There is no well established oscillation of similar period, *based on physical or dynamical considerations*, with which the fluctuation could be associated. Berlage[4,5] in an extensive study of over 50 alleged cycles of a year or more has argued that the so-called Southern Oscillation (a fluctuation, found by Sir Gilbert Walker in the pressure difference between the Malayan Archipelago and Easter Island) is a primary terrestrial period of $2\frac{1}{3}$ (2–3) years caused by mutual interactions of air and sea temperatures, the latter influenced by oceanic currents. As mentioned above, an attempt to find out whether there was any correlation between the zonal component of the tropical stratospheric winds and surface pressure proved unfruitful. Recent work in the U.S.S.R. (for example, Pokrovskaja[6]) has also suggested the existence of a two-year periodicity in certain elements, depression tracks, etc., but the details have not been studied. It is interesting to note that in a recent paper (Storebø[7]) on the exchange of air between stratosphere and troposphere, it is considered that about two years are required for the replacement of stratospheric air in the mean net circulation, suggested by tracer elements, by which air enters the stratosphere in the tropics, is transported polewards and leaves the stratosphere at higher latitudes. In any case, the finding presents a challenge to the theoretical meteorologists, and colleagues in the Climatological Research Division of the Meteorological Office are already studying the problem.

Acknowledgements.—Our thanks are due to the United States Weather Bureau and other meteorological services whose data have been used and to Dr. G. B. Tucker for his assistance in arranging for the correlation coefficients to be computed on "Meteor".

REFERENCES

1. VERYARD, R. G. and EBDON, R. A.; Fluctuations in equatorial stratospheric winds. *Nature, London*, **187**, 1961, p. 791.
2. EBDON, R. A.; Some notes on the stratospheric winds at Christmas Island and Canton Island. *Quart. J. R. met. Soc., London*, **87**, 1961 (awaiting publication).
3. HOPPER, V. D.; Importance of global study in the 30 km region. (Paper presented at symposium on Antarctic Meteorology at Melbourne, April 1959.)
4. BERLAGE, H. P.; The southern oscillation, a 2–3-year fundamental oscillation of world-wide significance. *Sci. Proc. int. Ass. Met. I.U.G.G., Rome* 1954. London, 1956, p. 336.
5. BERLAGE, H. P.; Fluctuations of the general atmospheric circulation of more than one year, their nature and prognostic value. *Meded. ned. met. Inst., De Bilt*, No. 69, 1957.
6. POKROVSKAJA, T. V.; On a two-year periodicity in the variation of meteorological phenomena. *Glav. Geofys. Obs., Leningrad*, **T.89**, p. 28.
7. STOREBØ P. B.; The exchange of air between stratosphere and troposphere. *J. Met., Lancaster, Pa.*, **17**, 1960, p. 547.

551.509.329: 551.509.59: 551.552

ACCURACY OF FORECASTING AIR TRAJECTORIES

By M. H. FREEMAN, O.B.E., M.Sc.

Introduction.—In the normal course of his work a forecaster often wants to know what air mass will be over his station some hours hence. Usually examination of current charts and prebaratics will give him a good enough answer without any elaborate methods, but sometimes more precision will be needed, and forecast trajectories will have to be drawn. Studies into the accuracy of prebaratics have been made in the past and it was thought that these could usefully be supplemented by an investigation into the accuracy with which air trajectories could be forecast.

Outline of investigation.—Birmingham was selected as the station for which trajectories were to be drawn and it was assumed that the problem was to find out what air originating over the sea would subsequently reach Birmingham. It was further assumed that the trajectories of the air could be determined from geostrophic winds measured from surface charts. This, of course, is not strictly true since the streamlines do not, in general, coincide with the isobars. However, if geostrophic winds are used for both forecast and actual trajectories a reasonable comparison can be made.

In order to simulate operational conditions the forecasts were made using current charts in the Central Forecasting Office at Dunstable; normal forecasting methods were used to produce a series of forecast surface charts. Between 0730 and 0900 GMT prebaratics for 1800 GMT and 0600 GMT were prepared for the British Isles and a wide surrounding area. Using these charts and the 0800 GMT actual chart, more detailed forecast charts were made for the British Isles on a scale of 1 : 3 million for 1200, 1800, 0001 and 0600 GMT. Trajectories were drawn on these charts in six-hour steps. Geostrophic winds were measured from the 1200 GMT map to obtain the air movement for the period 0900 to 1500 GMT, and successive sections of the trajectories were obtained from the remaining charts. By trial and error a starting point over the sea was chosen so as to give a forecast trajectory which passed over Birmingham. The position of this starting point determined the air mass which was expected

to reach Birmingham. It was decided also to obtain some information on the way in which neighbouring trajectories spread out or converged, so four more trajectories were drawn starting over the sea at distances of 50 and 100 miles on either side of the central starting point. Information was also sought on the success of forecasting trajectories over distances greater than that from the coast to Birmingham, so the trajectories were drawn for the whole 24-hour period, 0900 GMT to 0900 GMT, even though this usually took them well past Birmingham.

After the event actual charts were used by another forecaster to obtain "true" trajectories of the air starting at the five selected points. For greater accuracy hourly charts and steps were used over the British Isles; if the trajectories continued over the sea three-hourly steps were used since ship reports were not available more frequently than every three hours.

Between November 1959 and August 1960 forecasts were made on 40 occasions at approximately weekly intervals. On a few of them the trajectories became lost in the centres of depressions, but wherever possible measurements were made of the end points of the forecast and actual trajectories after 6, 12, 18, and 24 hours.

Results.—On the average the distance of Birmingham from the selected starting points was 160 miles and over this distance the forecasts were usually fairly accurate. Nevertheless on two occasions, both with light winds, the trajectories had not reached Birmingham after 24 hours. For the remainder the perpendicular distance from Birmingham to the central trajectory was, on the average, 25 miles. The frequency of errors of various magnitudes is given in Table I.

TABLE I—FREQUENCY OF ERRORS

Distance by which central trajectory missed Birmingham ...	0–10	20–40	50–80 mi
No. of occasions	20	11	7

On five of the seven occasions when misses of 50 miles or more were recorded the mean wind speed was about 10 knots, and on the other two occasions 20 and 30 knots.

Over distances greater than that of Birmingham from the sea, the accuracy in forecasting trajectories fell off. A measure of the error of a trajectory is the distance between the forecast end point and the observed end point and this error was recorded for each trajectory after 6, 12, 18 and 24 hours. In general the greater the trajectory length, the greater was the error. The mean errors and frequency of errors of various sizes for different trajectory lengths are given in Table II.

TABLE II—ERRORS FOR VARIOUS TRAJECTORY LENGTHS

Trajectory length (mi)...		110–200	210–400	410–600	610–800
Mean error (mi)		65	95	120	165
			per cent		
Frequency of errors of	50 mi or less	61	32	24	18
	100 mi or less	85	70	56	33
	200 mi or less	96	92	86	71
	400 mi or less	99	100	98	95

The greater errors for the longer trajectories are largely due to the time factor; as the period increases the reliability of the forecast wind field decreases. This is demonstrated in Table III, which shows the mean error and the frequency of errors of various sizes for trajectory times of 6, 12, 18 and 24 hours.

TABLE III—ERRORS FOR VARIOUS TRAJECTORY TIMES

		6	12	18	24
Period (hr)		6	12	18	24
Mean error (mi)		35	80	120	175
			per cent		
Frequency of errors of	50 mi or less	88	41	20	13
	100 mi or less	98	86	52	35
	200 mi or less	100	96	91	67
	400 mi or less		98	98	94

The errors are due partly to errors in forecasting wind speed and partly to errors in forecasting wind direction. The frequencies of errors of various sizes due to these causes are given in Table IV.

TABLE IV—ERRORS IN WIND SPEED AND WIND DIRECTION

Period (hr)	6	12	18	24
		per cent		
Speed errors of 5 kt or less	87	82	72	65
Speed errors of 10 kt or less	98	94	93	92
Direction errors of 10° or less	72	65	64	67
Direction errors of 30° or less	93	90	88	87

Good forecasts are more likely with some synoptic types than others. The most straightforward situation is a broad wind flow not changing markedly in direction. Twenty-three of the forty occasions could be classed in this category and sixteen of these were well or fairly well forecast. The larger errors on the others were mainly due to errors in forecasting the wind speed. As would be expected in these situations of a broad wind flow, errors in forecasting direction were generally small. The remaining situations included various synoptic types but were generally characterized by light winds, with ridges or highs predominating. In this group the proportion of good forecasts was smaller, and the larger errors were due mainly to wind direction being wrongly forecast.

The trajectories assumed interesting forms on a number of days. Convergence of the trajectories was marked on three occasions. The initial distance of 200 miles between the outside trajectories was reduced in the region of Birmingham to 70 miles on 8 December 1959, and to 100 miles on 26 January and 18 July 1960. The first was very well forecast but the others were not. On some days (for example, 30 December 1959 and 18 August 1960) the trajectories crossed one another. The crossing was well forecast on 30 December, and errors on both days were small. At the other extreme very divergent patterns sometimes occurred. On 15 March 1960 the initial 200-mile starting line had spread to 600 miles after 24 hours and this occurrence was quite well forecast. On two days, 14 December 1959 and 19 April 1960, air originating at either end of the starting line moved in almost diametrically opposite directions; these freakish occurrences were not correctly forecast. Another exceptional pattern occurred on 23 February 1960 when the trajectories started off in the general direction of Birmingham and then turned back on themselves. This was caused by the movement of a sharp ridge of high pressure and was fairly well forecast. There were rather similar situations on 30 May and 20 June 1960. On the whole most of the peculiar patterns occurred with light winds.

Acknowledgement.—The *post factum* drawing of the trajectories using actual charts was done by Messrs. A. R. Laird and P. F. Abbott.

CORRELATED FLUCTUATIONS OF WIND DIRECTION AND AIR TEMPERATURE AT RENFREW AIRPORT ON 12 OCTOBER, 1960

By J. B. McGINNIGLE

On 12 October 1960, between midnight and 0600 GMT, correlated fluctuations of wind direction and air temperature were recorded at Renfrew Airport. Intermittent fluctuations of 30 to 50 degrees in wind direction corresponded with almost instantaneous changes of two to three Fahrenheit degrees in air temperature.

Observational data.—Figure 1 shows the records of the two above-mentioned elements imposed on a common time-axis. The upper part shows the mean wind direction in degrees true over the six-hour period and was constructed from the anemograph chart for the period. The lower part of Figure 1 shows the recorded air temperature over the period, and this was constructed by combining observed temperatures with the trace of the thermograph. The recorded wind speed was consistently in the range five to ten knots and showed no variation at the times of wind direction fluctuation. For this reason it has not been reproduced.

Observed dew-point temperatures did not vary appreciably during the period, remaining at 33° – 34° F throughout, and the subsequent relative humidity range was 73 – 85 per cent. Visibility was good and one okta of cloud, base 5,000 feet, was the maximum observed amount between midnight and 0600 GMT.

The previous day's weather at Renfrew Airport had been typically convective, with broken cumulus cloud during the afternoon dispersing completely after sunset. The wind had been recording 10 – 15 knots from 320° – 350° during the afternoon, decreasing and backing to 5 – 10 knots from 290° – 310° during the evening. After reaching a maximum of 54° F the temperature decreased steadily to reach 42° F by midnight.

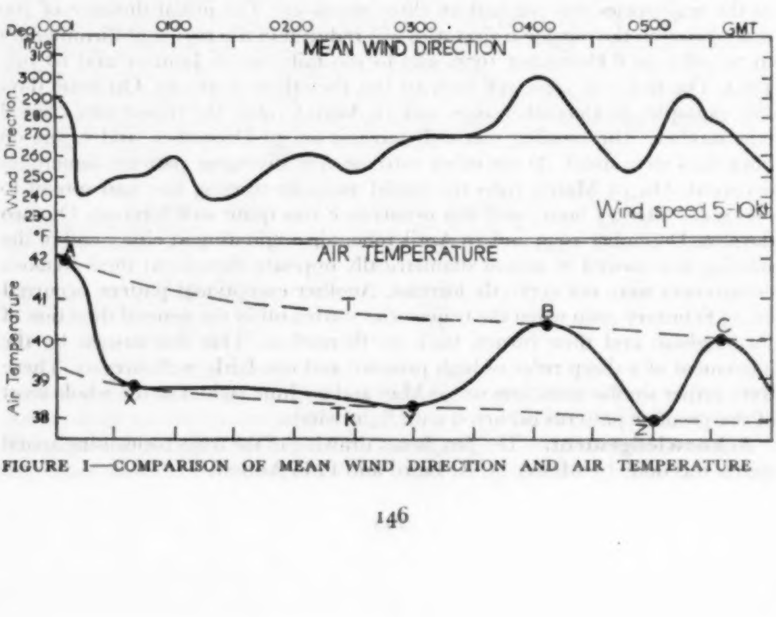


FIGURE 1—COMPARISON OF MEAN WIND DIRECTION AND AIR TEMPERATURE

Synoptic situation.—A simple synoptic situation existed over Scotland during the investigation period. A slow-moving depression over southern Sweden and an anticyclone over Iceland, ridging over the Atlantic, maintained an unchanging gradient for northerly winds of 25 – 35 knots over Scotland. The upper air ascents from Stornoway and Shanwell for midnight showed instability to 5,000 feet, with a surface temperature of 46° – 50° F, and an anticyclonic inversion above 5,000 feet. Between the top of the friction layer and 700 millibars there were no appreciable variations of wind speed and direction.

Topography.—Figure 2 shows the topography of the Clyde Valley and the position of Renfrew Airport between Paisley and Glasgow. From Renfrew Airport the ground slopes upwards gently to the north and south, but for the purpose of this investigation the significant features are situated in the north-west to south-west quadrant. The Clyde Estuary and the Valley lying along the line Dalry to Paisley are divided by the high ground of the Hill of Stake, which rises to 1,711 feet at a point approximately 14 miles west of Renfrew Airport. The slopes of this high ground are irregular and hold many stretches of water, the largest of which are reproduced in the sketch map. Thus there are two natural wind "channels" in this quadrant, and this "channelling" effect is often noticed in the wind observations at Renfrew Airport. This effect is an important feature in this investigation.

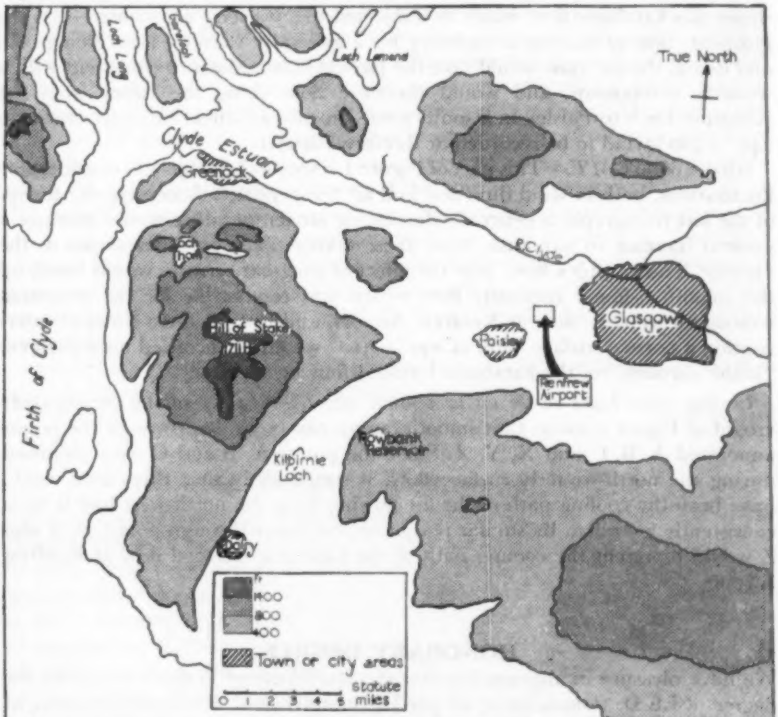


FIGURE 2—TOPOGRAPHY OF THE CLYDE VALLEY

Discussion.—The normal nocturnal wind direction recorded at Renfrew Airport in such a synoptic situation is 290° – 310° after flowing along the "channel" of the Clyde Estuary. From Figure 1 it will be noticed that between midnight and 0010 GMT, 0330 and 0430 GMT, and between 0505 and 0545 GMT, the wind flow was in this normal direction. At all other times in the period the wind direction was 240° – 270°, a direction which had a component against the gradient. This contra-gradient flow was almost certainly induced by katabatic effects, a theory which is upheld by the associated falls in air temperature (with no change of dew-point temperature) which occurred at the times of the onset of this flow.

It is at this point that Figure 1 should be considered in two parts, firstly to explain the theory of a contra-gradient flow existing at Renfrew Airport, and then, on the basis of this, to discuss the fluctuations of both elements later in the night.

Midnight – 0300 *GMT.*—This part of Figure 1 shows a smooth slow fall of air temperature after an initial plunge of 3·2 F degrees, while an approximately similar configuration in the wind direction record shows that after backing to 240° at 0015 GMT, the wind remained in a direction having a contra-gradient component until 0300 GMT. Following the katabatic theory, early katabatic flow would start in the most sheltered area, which in this synoptic situation would be the south-eastern slopes of the Hill of Stake. On reaching the lower slopes this katabatic flow would be subjected to a westerly component from the gradient, thus producing a tendency for a generally westerly flow. Being cold and dense, the air mass would take the path of least resistance consistent with a westerly component, and would therefore flow along the valley from the Kilbirnie Loch to Paisley in a south-west – north-east direction, thus causing a 240° – 260° wind to be recorded at Renfrew Airport.

0300 – 0600 *GMT.*—This part of Figure 1 is seen to be subject to considerable fluctuations, both in wind direction and air temperature. Accepting the theory of the last paragraph, a generally decreasing air temperature would produce a general increase in katabatic flow, these taking place on other slopes in the vicinity. This complex flow, plus the effect of irregular terrain, would break up the smooth original katabatic flow which was responsible for the persistent west-south-westerly flow at Renfrew Airport, and thus at these times of interruption a normal surface wind of 290° – 310° would be recorded until the next "break through" of the katabatic induced flow occurred.

Cooling curves based on the air temperature record.—A study of the temperature record of Figure 1 shows that smooth curves can be drawn through the points annotated A, B, C and X, Y, Z. Since the points A, B and C were recorded during the north-westerly surface flow, it seems likely that this curve would have been the cooling path of the air flowing from the north-west had it been consistently recorded. By similar reasoning, the curve through points X, Y and Z would represent the cooling path of the katabatic induced flow at Renfrew Airport.

HONORARY DEGREE

We have pleasure in announcing that the University of Wales is to confer the degree of LL.D. (*honoris causa*) on the Director-General, Sir Graham Sutton, at a ceremony to be held in Cardiff on 21 July 1961.

REVIEW

Radioactive wastes, their treatment and disposal, General Editor, John C. Collins. $8\frac{1}{2}$ in. $\times 5\frac{1}{2}$ in., pp. xxi+239, *illus.*, E. and F. N. Spon Ltd., 22 Henrietta Street, Strand, London, W.C.2, 1960. Price: £2 15*s*. 0*d*.

The problem of the disposal of radioactive wastes is an important aspect of the increasing use of radioactive materials for the production of power, in industry and in laboratories. It is essential that these wastes should be dealt with in such a way that no member of the public is in any danger from the radiations they emit. The publication of this book, which deals with practically all aspects of the problem, will be welcomed by all who are in any way connected with the disposal of such wastes.

Eight authors have contributed to the book, almost half of which is devoted to a brief account of the nature of radioactivity, its measurement and the biological effects of radiation. This half is far too condensed to be of any great value to anyone wishing to learn the fundamentals of radioactivity, but the rest of the book, dealing with the source of radioactive wastes, their treatment and disposal, gives a good account of the practical problems and the way in which they are overcome. A full bibliography is given with each chapter.

The chapter on the discharge of radioactive effluent into the atmosphere is the only one that concerns meteorologists as such, the problem being to determine the maximum amount of radioactive material, gas or vapour, that can safely be released into the atmosphere. In contrast with the other chapters in this part of the book, the discussion is almost entirely limited to theory. After a very brief discussion of the behaviour of the effluent plume under various temperature gradient conditions, the author shows how Sutton's equations can be used to estimate the distribution of effluent downwind from a ground-level source or a stack, and compares some experimental results with calculated values. No mention is made, however, of the effect of topography on the values of C_y and C_z. Topography could also be an important factor in its effect on local winds, especially under strong inversion conditions. The importance of sampling to check the levels of activity in the neighbourhood of the point of release is glossed over very quickly. Practical points such as these should undoubtedly have been included, bearing in mind the type of reader for whom the book is intended.

On the whole, the book should serve its purpose quite well, but it is rather expensive even by present-day standards.

J. CRABTREE

METEOROLOGICAL OFFICE NEWS

The first Gassiot Fellow will take up appointment in May 1961. He is Frank Donald Stacey, B.Sc., Ph.D., aged 31, a graduate of Queen Mary College, London. After presentation of an experimental thesis on "Ferromagnetism at high pressure", he accepted a Research Fellowship in the Physics Department at the University of British Columbia from 1953 to 1956. He comes to the Meteorological Office from the Australian National University, Canberra, where he was holding a Research Fellowship in Geophysics. He is interested in the mechanics of the Earth, rock-magnetism, the physics of ionization and fundamental and solid state ferromagnetism. Dr. Stacey is married with two young children.